Developing Key Optometric Skills Handbook

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Foreword

Following the successful establishment of the GOS Eye Exam Contract in 2006, the Scottish Government’s Health Directorate recognised the increasing role Optometry is playing in primary health care by supporting the ongoing education and training of optometrists with a £1m annual fund to be administered through NHS Education for Scotland (NES).

One of our initial priorities was to encourage every optometrist to become skilled in the use of volk lenses, advanced slit lamp technique, contact tonometry and anterior angle assessment - including gonioscopy. These techniques should no longer be considered “advanced investigative techniques” but part of the skills which the public should expect of all optometrists.
Chapter 1

Indirect Ophthalmoscopy

A thorough examination of the ocular fundus is mandatory in any eye examination. The routine employed by the practitioner will largely depend on the specific history and symptoms a patient presents with. Factors such as age, systemic medication and race may also play an important role and may warrant adaptation to the practitioner’s normal routine.

To dilate or not?
There can be no argument that fundus examination is greatly facilitated by dilating the pupil. However, the decision of whether or not to dilate a patient (or indeed every patient) must be based on reasoned clinical decision-making, particularly as an adequate fundus examination can be performed with most instruments without pupil dilation. The advantages of an enhanced fundus view must generally outweigh any negative effects of pupillary dilation.

It is still a concern of some practitioners that pupil dilation may induce angle-closure and lead to an attack of glaucoma. Although the roots of this statement are solid, the incidence, which is often quoted around less than 1:100,000, is very small. Indeed, there are experienced practitioners who readily dilate patients, who have never witnessed such an event in their lengthy career. It is important however, not to be frugal with dilation and it is essential that all the risk factors are eliminated before attempting to dilate an individual.

Normal history and symptoms may pinpoint individuals who might have a predisposition to angle closure. Slit lamp examination may also be useful in identifying patients with iris/angle anomalies who may also be at risk. An assessment of the anterior chamber depth can be obtained using a Van Herrick technique. However, it is important to bear in mind that a patient with a shallow anterior chamber depth by this technique is not necessarily at risk of closure. The cautious practitioner may also want to determine intraocular pressure (IOP) pre-dilation and repeat this measurement approximately 30 minutes after maximum dilation has been achieved. Any significant rise in IOP (>5mmHg) is indicative of angle-closure and would warrant immediate referral to a casualty department.

In addition to those with shallow-angles or risk factors that may precipitate angle closure, it is accepted that there are a number of patients for who dilation is contraindicated. These are:

• Patients with history of penetrating injury  • Patients with iris-clip intra ocular lenses

Driving following pupil dilation is generally contraindicated, however, for patients who need to drive home following an eye examination a supplementary appointment can be made for fundus examination, on a day that they do not have to drive or when they can be accompanied. An exception to this last point is when the patient presents with symptoms indicative of a serious retinal pathology, such as a detachment. Here the patient must be dilated immediately as a thorough examination is required.

There is some debate as to which pharmacological agent should be used to dilate a pupil. The choice of drug may vary with each patient and the nature of the examination to be performed. For example if fundus examination and a cycloplegic refraction in a young patient are required there is very little point in using a mild miotic drug. Any drop used should be fast acting, able to be effective for the full duration required, minimally toxic, have low risk of any side effects (local or systemic) and have a quick recovery time.

Most authorities advise using either of the following combinations:

One drop of 2.5% phenylephrine (stimulating the dilatator pupillae of the iris) together with one drop of 0.5% tropicamide (restricts the action of the sphincter pupillae). The synergistic action of these 2 drugs produces maximal pupil dilation and improves patient comfort as it restricts pupil constriction during examination.

Two drops of 0.5% tropicamide instilled a minute apart. The choices above are not prescriptive and the practitioner may modify their choice based on factors such as age of patient, race or patients general health. It is important to bear in mind that dilation can be facilitated up by instilling one drop of topical anaesthetic prior to instillation of the dilating drop(s), as this increase the permeability across the cornea.
Instillation of drops
A number of simple precautions are essential when instilling drops. Most practitioners use single dose units, Minims, for ophthalmic drugs, but where multidose drops are used it is essential to assess the patency of the bottle and not use any where there appears to be any damage. In all cases, when instilling drops;

• Check the date of expiry as old drugs are less effective and may even cause ocular surface reaction.

• Check the drug and dose is the one wanted.

• Check that the patient has had no previous adverse response to a drop – though unlikely, this may be useful in cases where there has been IOP changes in the past.

• Wash hands.

• Getting the patient to look upward, the lower lid may be pulled down gently and a single drop instilled in the lower fornix. This avoids any risk of corneal contact were the patient to flinch suddenly or flick their eyes up in a Bell’s movement.

• Never let the delivery unit touch the patient.

• The same unit is usable for both patient eyes.

• Issue a leaflet summarising the exact nature of the drop action and any symptoms to report, to whom, in the unlikely event of an adverse response. Examples of these are available from the College of Optometrists website.

The theory behind indirect ophthalmoscopy
Direct ophthalmoscopy, rather unsurprisingly, allows direct viewing of the patient fundus. This is achieved by the focusing of light from a lamp via an array of condensing lenses onto a mirror which reflects light to a focus on the patient retina. This is then viewed via a sight hole by the observer, usually through a hole in the mirror. A battery of lenses ensures adequate focus of the patient retina irrespective of patient and observer ametropia, and filters and stops allow a variety of fundus views. The positioning of the hole usually above the light source at the mirror leads to an uneven retinal illumination with inferior views often darker. This is exacerbated by the increasingly elliptical pupil as one looks further down into the inferior fundus leading to the familiar ‘shadow’ seen in many patients.

Indirect ophthalmoscopy requires the observer to view an image of the fundus that has been projected to a point in space. This is usually by means of a high powered positive lens which therefore forms an inverted aerial image immediately in from of the lens held before the patient eye. The observer therefore requires some form of viewing instrument. This is usually a slit-lamp, but also head set viewing lenses are used. In this case the light source is nearer to the patient eye but laterally displaced such that the incident and reflected paths are different. This has the advantage of both increasing the fundus view through media changes (such as cataract or corneal transparency loss) and improving the contrast view of various lesions such as naevi which may not be visible under direct view. As will further be discussed, the technique also offers the advantages inherent in the viewing system, such as binocularity, filter and rheostat adjustment, easy image capture, and a more comfortable viewing distance (for both parties!).

Direct ophthalmoscopy
The direct ophthalmoscope still remains the favoured instrument of many practitioners. It is probably because of its ease of use and magnified view that this instrument has so long been at the vanguard of fundus examination. As this was the instrument that most practitioners used routinely during perhaps this is why it has become an inherent part of most clinicians’ armoury.

The direct ophthalmoscope has many positive features and used in conjunction with an indirect ophthalmoscope, fundus examination can be optimised. Table 1 below lists some of the major benefits and pitfalls of the direct ophthalmoscope.
Table 1. Features of the direct ophthalmoscope

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>High magnification (x15)</td>
<td>Magnification varies with the patient’s refractive error. Higher in myopes</td>
</tr>
<tr>
<td>Relatively good image obtained even through a</td>
<td>Very low field of view (around 10°) in an emmetrope</td>
</tr>
<tr>
<td>small pupil</td>
<td></td>
</tr>
<tr>
<td>Portable</td>
<td>Monocular field of view</td>
</tr>
<tr>
<td>Relatively inexpensive</td>
<td>Can be difficult to use on uncooperative patients</td>
</tr>
<tr>
<td>View of fundus is the correct way up and non-</td>
<td>Image degrades with media opacities. Poor at showing colour change or elevation.</td>
</tr>
<tr>
<td>reversed</td>
<td></td>
</tr>
</tbody>
</table>

The low field of view makes the direct ophthalmoscope difficult to use when scanning across the fundus, with only small areas being visible at any one point in time (see figure 1). This becomes particularly relevant when an overall view of the posterior pole is required such as in a diabetic. A small pupil and media opacities further heighten this problem. The difficulties are minimised by dilation. Therefore, for a patient with small pupils and/or media opacities, pupillary dilation is recommended to perform a thorough examination.

Fig 1a.

View of fundus as might be seen using a slit lamp with fundus viewing lens.

Fig 1b.

Shows a typical highlighted area as may be seen with a direct view of a high myope. Note the very limited field of view related to the ametropia.

The monocular view of the direct ophthalmoscope renders judgement of depth difficult and the observer has to rely on other cues to form an opinion. A useful addition to most modern direct ophthalmoscopes is
the inclusion of a slit graticule. This can be projected onto the fundus and any change in its regularity would indicate an area of elevation or depression.

**Wide field direct ophthalmoscopy**

Recently launched instruments claim to overcome some of the short falls of the direct ophthalmoscope. An example is the PanOptic from Welch Allyn. Using a patented optical system such instruments have 3 main advantages of the conventional direct ophthalmoscope. These are:

- **An enhanced field of view in the undilated eye, typically quoted to be in the order of 25º.**
- **A 26% increase in magnification.** This results in the image being a quarter bigger than with the standard ophthalmoscope, thus improving resolution of the retina, hence allowing fine detail such as vascular changes to be more easily viewed.

- **An increase in the working distance between patient and clinician, allowing improved comfort for both.** The optic of such systems differ from the conventional direct ophthalmoscope in that they allow light to converge to a point at the cornea and then diverge towards the retina, allowing for a wider field of view. In a standard ophthalmoscope, light is projected directly onto the observer’s retina. The image produced is erect and not inverted. This point convergence makes the distance from the patient a crucial factor in maintaining a good field of view and a common error among inexperienced users of such instruments is to fail to adopt a close enough viewing position and therefore never achieve the described benefits.

**Fundus contact lenses**

Although there are a number of lenses available on the market, probably the best-known fundus contact lens is the Goldmann three-mirror lens (figure 2). Fundus contact lenses provide the best degree of stereopsis of all of the methods of examination. Additionally, they allow the observer to view the extreme periphery of the fundus, as well as the central region. It is perhaps fair to say that these lenses haven’t really taken off in popularity in general optometric practice, as they are perceived difficult to use. Moreover, the need to contact the surface of the eye (albeit with a coupling fluid in place) is off putting to the majority of practitioners.

![3-mirror fundus viewing contact lens](image)

But possibly the most significant factor as to why these lenses have now become relatively obsolete is because optical and government agencies have advised against the use of procedures that involve direct contact with the cornea when the device has already been in contact with the cornea of another person, unless required, because of a theoretical risk of transmitting the variant Creutzfeldt-Jacob disease (vCJD).
prion. This was based on advice given by SEAC, the Spongiform Encephalopathy Advisory Committee to the Department of Health (DOH) in 1999.

The College of Optometrists and Association of British Dispensing Opticians have recommended guidelines for sterilisation in response to the warning. However, the recommended decontamination procedure (one hour in 2% Sodium Hypochlorite solution followed with rinsing in sterile saline) is only for RGP contact lenses. The efficacy of the procedure for sterilisation of other instruments is still under research. Therefore, while this advice is still in place and alternative non-contact methods are available, these lenses are generally confined to the back of the drawer.

**Slit lamp binocular indirect ophthalmoscopy (BIO)**

This technique has gained huge popularity in recent times, such that many practitioners have incorporated the use of hand-held indirect lenses to view the fundus into their general routine. It is also a required General Optical Council core competency skill for qualifying optometrists. Indirect lenses are high-plus lenses that are used in conjunction with a slit lamp to produce a virtual image of the fundus that is laterally reversed and inverted. Therefore the clinician that is new to this technique has to adjust their observation to account for an upside down, mirror image.

There are a number of lenses available on the market. They are available with a number of modifications. These include:

- **Yellow filters** – that are either fixed or detachable. This reduces the amount of blue light impacting on the fundus, which is important in prolonged examinations;
- **Lid adapters** – that help separate the lids and set the lens at the correct working distance;
- **Graticules** – that are useful for measuring; or
- **Mounts** – which steady the lens on the slit lamp.

The best field of view is obtained by the higher dioptic powered lenses, but at a compromise to working distance. Each lens produces a stereoscopic fundus view that is only marginally magnified, with the greatest magnification being achieved with the lower powers. The slit lamp’s observation system is utilised to increase the magnification of the image. Table 2 below lists some of the properties of lenses that are commercially available. The information has been collated from the manufacturer’s data. Note how, generally speaking, the higher the power of the lens, the greater the field of view but the lower the magnification. This is important. It is tempting with a slit lamp to keep using one single viewing lens for all occasions and to adjust the magnification using the slit lamp. This, however, reduces the crispness of the image. It is therefore preferable to keep a lower power lens (say a 60D) for accurate viewing of specific areas or lesions, such as disc or macular, and a higher powered lens (say a Superfield) for wider views, as would be needed for a multifocal lesion disorder such as diabetic retinopathy. Most regular users would confess to owning at least two lenses.

**Table 2. A comparison of the different hand-held indirect lenses**

<table>
<thead>
<tr>
<th>Power (D)</th>
<th>Magnification</th>
<th>Field of View (°)</th>
<th>Working distance from cornea (mm)</th>
<th>Indications for use</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1.15x</td>
<td>76</td>
<td>11</td>
<td>Disc and macula</td>
</tr>
<tr>
<td>78</td>
<td>0.93 x</td>
<td>84</td>
<td>8</td>
<td>General screening</td>
</tr>
<tr>
<td>90</td>
<td>0.75x</td>
<td>94</td>
<td>6</td>
<td>General screening. Works well with small pupils</td>
</tr>
<tr>
<td>SuperField</td>
<td>0.76x</td>
<td>95</td>
<td>7</td>
<td>General screening. Works well with small pupils</td>
</tr>
<tr>
<td>Variable zoom</td>
<td>0.77-0.94x</td>
<td>78-100</td>
<td>5</td>
<td>General screening</td>
</tr>
<tr>
<td>132 SP</td>
<td>0.45</td>
<td>99</td>
<td>4</td>
<td>Wide field, small pupils</td>
</tr>
</tbody>
</table>

Another simple point is that the lenses described with the ‘super’ prefix, such as the SuperPupil and the SuperField, are not equi-convex so need to be held with the tapered edge (figure 3) towards the patient. The other lenses may be held either way.
A SuperField lens in side view. The tapered edge needs to point towards the patient.

**Examination technique**

- For the best results, the pupil is dilated with an appropriate pharmaceutical agent(s).
- Patient is instructed on the need for maximum compliance and asked to fixate the slit lamp fixation target.
- The microscope is placed in the straight-ahead position with the lamp coaxial (allowing binocular viewing). The magnification is set to its lowest position and slit adjusted to a height around 5mm and width 3-4mm.
- The slit is focussed on the patient’s cornea and centred. The lens is introduced close to the patient’s eye (figure 4). The lens needs to be orientated accordingly if it is not equi-convex as mentioned earlier.

The lens is held before the patient’s eye. If not at the correct working distance for the lens, a full stereo view will be unlikely.
• Each lens will have a working distance at which it should ideally be held from the patient eye. It is important to maintain this distance to offer a binocular view. The working distances vary from lens to lens but are generally between around 8 and 12mm, much less that most people might imagine. For this reason, many practitioners are happily using their lenses and achieving monocular views. Always check that the fundus view is visible to both eyes and if not, the lens needs to be positioned closer to the patient.

• The slit lamp is moved away from the patient until the inverted image of the retina (usually a thin vertical strip at this stage) is seen (figure 5). At this stage, fine movements of the joystick allow finer focusing, and adjustment of the slit width and rheostat may be made optimal for the needs of viewing but also to minimise discomfort for the patient (the brightest widest image may not always be appreciated).

Fig 5.

The first view of the retina is usually a thin vertical strip. Accurate focusing and adjustment of brightness and slit width is essential at this stage.

• Focussing just before the retinal surface allows investigation of the vitreous, which can be particularly useful in posterior vitreous detachment (PVD) where a Weiss ring might be visible (figure 6).

Fig 6.

Weiss’ ring may be viewed by focusing anteriorly to the retinal plane

• By bringing the lens closer to the eye the field of view can be increased. Any reflections from the slit lamp can be minimised or eliminated by slightly tilting the lens either vertically or horizontally.

• The image can be optimised by adjusting the magnification and slit width/height on the slit lamp.
The eye is examined in various positions of gaze. The lens is repositioned each time to optimise the view. If the observer requires the image to move then the lens is moved in the same direction as the desired movement.

A good systematic approach for full fundus examination might be;

- **Start at the disc and not all salient features** – check that the view is stereoscopic as this will help to interpret disc topography.

- **Move the slit lamp nasally to the disc and cross the foveal region, noting all vascular, pigmented and other features, and noting the foveal quality without dwelling there to avoid patient discomfort.** This same method should allow scanning of most of the macular and peripapillary region without patient eye of lens movement, bar any subtle tilting to minimise reflections.

- **Asking the patient to look up allows viewing of the superior retina.** Once they look up their pupil will obviously move up too so the lens will accordingly have to be moved up until in front of the pupil at which point a retinal view will again be seen. Excessive reflections in this position may be minimised by maintaining coaxial illumination by tilting the lens top away from the patient slightly. The same should be repeated for all 8 positions of gaze.

- **Remember the view is laterally and vertically reversed.** Some practitioners prefer to invert the record card when noting appearance. In the superior position of gaze, as described above, the view is of superior retina but the far periphery will be in the inferior field of the viewer and the mid-periphery in the superior field. When a patient looks nasally, nasal retina is viewed, the lens tilted so that the most nasal aspect of the lens is tilted away from the patient, and the far nasal periphery is in the temporal field of the viewer.

Slit lamp BIO can be used to examine a patient with undilated pupils. The lenses, such as the SuperPupil which are specifically designed for use on a small pupil, work best in these instances. Nonetheless, a good view of the disc can be obtained in most patients. BIO has many advantages but also has some disadvantages. These are listed below in table 3:

**Table 3. Benefits and pitfalls of slit lamp BIO**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide field of view making it easy to scan fundus</td>
<td>Image is virtual, laterally reversed and inverted</td>
</tr>
<tr>
<td>Image degrades significantly less with media opacities compared with direct methods</td>
<td>Magnification and image quality limited by slit lamp</td>
</tr>
<tr>
<td>Excellent in detecting stereoscopic and colour changes</td>
<td>Difficult to use on small pupils</td>
</tr>
<tr>
<td>Inexpensive (assuming slit lamp is available)</td>
<td>Difficult to use on non-compliant patients</td>
</tr>
<tr>
<td>Magnification does not vary with patient’s refractive error</td>
<td>Unsuitable for domiciliary work, patient has to be upright</td>
</tr>
<tr>
<td>Comfortable distance from patient maintained</td>
<td>Needs practice to become proficient</td>
</tr>
</tbody>
</table>

Whatever lens is used, it is essential to keep it completely clean at all times. A good quality lens cloth and cleaning fluid is advised. Alcohol based cleaners are never a good idea (for example a Medi-Swab) as they may dissolve the cement holding the lens in its case and result in the all too familiar ‘rattle’ that many older lenses emit in use.

**Head-borne binocular indirect ophthalmoscopy**

The headset BIO is used in conjunction with a condensing lens and best results are obtained when the pupil is maximally dilated. The condensing lens, typically a lower powered lens such as 20D, collects the image of the retina from the patient’s eye. The optometrist views this image binocularly. Greatest magnification is achieved with a low powered condensing lens; however, this compromises the field of view. Higher-powered lenses have to be held closer to the patient.

The field of view that is produced is approximately 10x wider than that achieved with direct ophthalmoscopy. The binocular viewing conditions ensure good stereopsis and there is negligible change in magnification with the patient’s refractive error. The image produced by a headset system is laterally reversed and upside down. The most peripheral part of the image is seen in the opposite direction to the patient’s gaze, so on looking up, the superior periphery is seen at the bottom of the image.
The wide field of view produced by this technique makes it ideal for examining the peripheral fundus however; its low magnification can lead to subtle changes or small lesions being missed. The first time an instrument is used by a practitioner adjustment of the headband is required. This is done as follows:

- Slacken the head size and height adjustment knobs and place the headband on the head like a hat.
- Tighten the height adjustment control until the headband sits level on the head and is located about 2cms above the eyebrow. Tighten the head size adjustment knob to comfortably lock the unit into position. It should not feel excessively tight but be stable.
- Slacken the browbar knob and the hinge adjustment control to locate the eyepieces level with the eyes and as close as possible to them. Tighten the knobs to maintain this position.
- Providing the unit is used by the same practitioner, the above should not need to be reset each time it is used. The oculars of the observation system then need to be set accurately for the examiner:
  - Look through the eyepieces at an object about 40cm away (eg one’s thumb).
  - Slide the two knobs for PD adjustment laterally while looking monocularly through each eyepiece so that view of the object is centred exactly in front of the eye.
- Move the illumination beam so that it overlaps an object in the centre of the field of view through the eyepieces.
- Select the appropriate beam size. Generally, the largest beam will be most suitable for peripheral examination. Smaller diameters are better for undilated pupils or high-power lenses. Put the diffuser (if available) into the system as it improves the peripheral view.
- A filter can be selected if appropriate, although for peripheral assessment white light will generally be used. The observational technique requires practice and it will require several weeks of experience before the practitioner will be confident. The procedure is as follows:
  - Instruct the patient that their eyes are going to be examined using a bright light but that it will not be at all harmful. Both eyes should remain open throughout the exam.
  - Lie the patient down in a darkened room so that they are at waist height and their head is in front of the examiner.
  - Start by examining the superior periphery. This will entail the patient looking up and the examiner standing 180 degrees in the opposite direction ie towards the patient’s feet.
  - Once the red reflex is seen, insert the lens with the steeper curvature of the bi-aspheric lens facing the examiner. The side facing the patient has a silver or white band at the edge.
  - Hold the lens parallel to the patient’s iris plane and a short distance from the cornea with the fingers steadied on the patient’s forehead or cheek.
  - If necessary, hold the lids apart with the fingers of the other hand.
  - The anterior segment of the eye should be seen through the lens with a red reflex in the pupil.
  - Move the lens away from the eye until the fundus image fills the lens, but not so far that an inverted minified image of the anterior segment is seen.
  - Adjust the illumination, if necessary, to the minimum permitting clear visualisation of fundal details.
  - Progressively cover all peripheral quadrants by getting the patient to adjust the direction of gaze and moving to a position opposite to the gaze direction. The lens will need to be re-aligned each time. Tilting the lens can improve the image dramatically by moving the lens surface reflections out of the examiner’s way.
  - Finally, examine the posterior pole, limiting exposure time to reduce dazzle.
• Release the lids before each re-fixation to allow the patient to blink and separate as necessary to improve your view.

**Scleral indentation**
This is usually essential should the examiner wish to examine to the extreme periphery. The compression of the sclera caused by pressure from a scleral indentor (figure 7) places the ora serrata within the field of view of the headset BIO. In addition, it permits a kinetic evaluation of the peripheral retina to be made.

*Fig 7.*

**A scleral indentor**

Any break in the retina located beyond the equator will move or be more easily seen on indentation. However, it is not easy and should not be attempted until the art of this type of BIO has been mastered. While scleral indentation does not make retinal lesions worse or cause a detachment, it should not be attempted in any eye that has had intraocular surgery in the past 8-10 weeks because the large increase in IOP it temporarily produces could cause damage. It should not be used if the eye has had a penetrating or orbital injury. The technique is as follows:

• A thimble-type scleral indentor is placed on the first finger of the dominant hand.

• The indentor should always be tangential to the eye and wherever possible the force should be applied through the lids, beyond the tarsal plates.

• The patient looks initially in the opposite direction to the region to be viewed. The superior temporal region is easiest to examine.

• Therefore, start with the patient looking down. Press the indentor on the upper lid behind the tarsal plate. Remember the ora begins at least 7mm behind the limbus.

• With the indentor gently pressed against the eye, ask the patient to look up. At the same time advance the indentor parallel to the globe back into the anterior orbit.

• While looking through the headset the indentor is pressed into the eye, applying force tangentially. The mound produced in the superior retinal periphery is seen like a mouse under a carpet and appears darker than surrounding tissue.

• The indentor should be removed and the procedure repeated at each clock hour while working clockwise over the eye. The motion of the mound (or mouse) is observed, whilst keeping the examiner’s eyes, the condensing lens, the fundus image and the indentor all in a straight line.

• At the three and nine o’clock positions indentation can be done by dragging the lids from the 10 or two o’clock position. If this is not possible then gentle pressure on the conjunctiva itself may be required, with or without anaesthesia.

**Modified (monocular) indirect ophthalmoscopy**
Examination of an uncooperative patient is difficult. Many of the techniques described above require patient compliance. The direct ophthalmoscope generally offers the best solution, but it too has difficulty – patients
often fret as the clinician approaches and moreover, the patient is most likely to fixate the ophthalmoscope light. This generally results in good view of the fovea and macula but little else! The direct ophthalmoscope can be used in conjunction with a condensing lens. This provides the observer with a moderately magnified and wider-angle view of the posterior pole. An inverted, laterally reversed image is produced. A magnification of 4-5x is achieved which can be increased slightly by the practitioner moving closer. It also allows the clinician to work at 20-50cms from the patient, thus allowing for the anxious patient.

This technique is particularly useful for viewing the central fundus in children and with practice the practitioner is able to get a reasonable view of the disc and macula. The main disadvantage of this technique is the lack of stereopsis. However, lateral movement to induce parallax, can provide clues to depth perception.
Chapter 2

Contact Applanation Tonometry

When should IOP be measured?

- There are many indications for tonometry to be carried out. Most practitioners, aware of the link with open-angle glaucoma, the major risk factor for which is age, measure IOP routinely on all patients over a certain age. 40 years of age is a cut off point where epidemiological studies suggest the incidence of glaucoma becomes significant. 1-2.1% of Caucasians and 4.7-8.8% of Afro-Caribbeans over the age of 40 years suffer the disease. The incidence increases dramatically to 3.5% Caucasians and 12% Afro-Caribbeans over the age of 70 years. These figures, and the great variability of the disease, are both reflected in the occurrence of open-angle glaucoma in the under 40’s, so this author measures IOP on all patients over 30 years of age.

- It is also often useful to have a baseline measurement of IOP on all patients for interpretation of any future readings taken.

- IOP is also routinely measured prior and subsequent to dilation. A rise of more than 5mmHg which fails to stabilise may be indicative of an induced angle closure requiring medical attention. One should also remember that cycloplegic drugs may interfere with aqueous flow and IOP measurement, even in the very young, may need to be considered.

- Younger patients may present with signs that may indicate a risk of secondary open-angle or primary and secondary closed angle glaucoma, for example a very narrow angle or the presence of material on the corneal endothelium or in the anterior chamber. An IOP measurement would be useful in these instances.

- Symptoms suggesting possible retinal damage (photopia, floaters) may prompt tonometry to see if there has been a significant fall in pressure.

Techniques of measuring intraocular pressure

There have been many methods used to measure IOP, some more successfully than others and those that are likely to be used or have been used widely in the past are mentioned below.

Before discussing some mechanical methods available, some mention should be made of digital palpation. Despite this method being largely discounted as inaccurate by many authorities, the palpation of the superior sclera by the forefingers of both hands on the closed eyes is still used, often by practitioners who claim great accuracy. Certainly, a large difference between the eyes should be detectable to an experienced practitioner and there may well be situations, in an emergency for example, where it is the only available technique.

Tonometry relies upon the application of external force causing deformation of the cornea (or the sclera in eyes where this is not possible such as when anaesthesia cannot be used and the cornea is grossly scarred) and relating the deformation to the eyes internal pressure. The tonometers may thus be classified according to the deformation produced.

Indentation or impression tonometry

These rely upon a plunger of variable weight to deform the cornea by a shape resembling a truncated cone. The level of indentation with differing weights is related to the IOP. The prototype and most famous indentation tonometer is the Schiotz. For many reasons, not least patient compromise and the effects of ocular massaging, this technique is now largely obsolete in the UK.

There has been some renewed interest recently in indentation tonometry. The use of electronic measurement to assess recoil of a magnetically projected probe, so small that no anaesthetic is required, is employed in a new instrument (the i-Care tonometer) currently undergoing clinical evaluation at the time of writing. Another new product, the Diaton, uses indentation through the closed lid and assesses intraocular pressure without anaesthesia. Results vary with lid tension and this author believes the instrument to be best used if other techniques are not available.

Applanation tonometry

As suggested by the name, this technique relies upon the tonometer flattening or applanating an area of cornea. The weight applied may be related to the pressure within and the area applanated by the application of the Imbert Fick Law (also originally known as the Maklakov-Fick Law).
This law states that an external force (W) against a sphere equals the pressure in the sphere (P1) times the area applanated or flattened by the external force (A). This physical law assumes that the sphere is perfectly spherical, dry, perfectly flexible and infinitely thin. The cornea fails to satisfy any of these criteria. It is aspheric, wet, and neither perfectly flexible or infinitely thin. The tear film creates a surface tension which has the effect of drawing the applied weight onto the eye (S), while the lack of corneal flexibility requires an extra force to deform the cornea. Furthermore, as the cornea has a central thickness of around 0.55 mm, the area applanated is larger on the external surface (A) than the internal surface (A1).

To overcome this, the Imbert-Fick law may be modified to:

\[ W + S = P1 A1 + B \]

Where B represents the force needed to bend the cornea. When A1 is 7.35 mm, then S balances out B and therefore:

\[ W = P1 \]

An area of 7.35 mm has a diameter of 3.06 mm and the above cancelling out holds true for areas of diameter between 3 and 4 mm. 3.06 mm is useful because if that diameter is chosen then an applied force of 1 g corresponds to an internal pressure of 10 mmHg so making calibration of any applanating instrument easier. Furthermore, the volume displacement for this applanation is approximately 0.50 mm such that ocular rigidity does not significantly affect the reading. Ocular massaging plays no part in applanation either.

It is increasingly being recognised that the resistance to the deforming force offered by the cornea is strongly associated with the thickness of the cornea. The thicker the cornea, the higher the measured IOP irrespective of its actual value. For this reason, most practitioners requiring accuracy of tonometry also take a pachymetry reading. It is also useful to know by how much a patient’s IOP reading needs to be adjusted after they have undergone refractive surgery. Their thinner corneas will offer less resistance to the force of contact applanation and give an artificially reduced reading to that found prior to surgery.

The very first applanation tonometers employed a fixed weight applied cause a variable area of applanation, such as the Maklakoff, Tonomat and Glaucotest instruments. These instruments are now rarely used as, with a lower IOP, a force can applanate a larger area so promoting aqueous displacement.

Much more widely used and usually taken as the standard technique is that of Goldmann where there is a variable weight and a fixed (7.35 mm) area.

Goldmann contact tonometer
This instrument is widely used and is generally accepted as the international standard by which other instruments are compared and with which the vast majority of research in IOP measurement is carried out.

The applanation is caused by the probe that consists of a cone with a flat end containing two prisms mounted with their apices together. On contact with the cornea, the tear film forms a meniscus around the area of contact and the ring so formed is seen by the practitioner through the probe. The split prism allows the ring to be seen as two semicircles which may be moved in position relative to one another by varying the weight of the probe applied to the cornea.

This use of a vernier reading method adds to the accuracy of the instrument and when the inner edges of the semicircles just touch then the diameter of the applanated is 3.06 mm. The basic instrument itself, into which the cone is inserted, is basically a lever weight system with an adjustable scale, the scale calibrated in grams to allow varying force to be applied to the cornea by the probe when the wheel is turned.

• The basic procedure for Goldmann tonometer use should always involve thorough cleaning of the probe head. As well as the common infective agents one may come across in the tear film, there have been reported cases of hepatitis B and HIV virus isolated in the tears. The need for disposable contact apparatus in the aftermath of the variant Creutzfeld-Jacob Disease scare has led to most practitioners using a disposable tonometer head (the most common being the Tonosafe) which is placed within the housing and orientated appropriately.

• Adequate sterilisation may be carried out with a weak solution of sodium hypochlorite. Though it is tempting to air dry the probe, dry residue of the cleaning agent has been found to occasionally aggravate the cornea so a rinse with saline is advised.
• The probe should be inserted so that the white marking on the head aligns with that on the instrument to ensure that the split between the rings is horizontal. For astigmatic corneas (of greater than 3.00 DC), it has been shown that the probe should be aligned such that the interprism face is set at 43° to the meridian of the lowest power then the area applanated is still correct. A little red marker on the probe head allows this adjustment for ‘with the rule’ astigmats.

• The cornea is anaesthetised (this author prefers 0.5% proxymetacaine which should cause less stinging and reactive tearing) and fluorescein instilled. Though difficult to quote an exact amount that would be meaningful in practice, too much fluorescein and therefore wide ring width will tend to give a high reading. If too little is instilled it is difficult to visualise the rings and vernier adjustment is less easy. It may be noted that some experienced clinicians carry out the procedure without any stain at all.

• The instrument is set on the plate on the slit lamp before the eye to be examined and this usually allows the probe to be directly slightly from the nasal aspect to allow the incidence to be on axis despite any slight convergence by the patient. To minimise the contact time with the cornea it is useful to set the instrument to a weight setting of 1g (10mmHg) or a previous reading if known. On low to medium magnification, the probe is viewed through the microscope with the cobalt blue light incident on the probe head, the lamp set at 60° temporally.

• The probe is moved on to the cornea and the rings visualised and adjusted as mentioned. If the semicircles are not of equal size then small vertical adjustments may be needed. Always move towards the larger semicircle. If the semicircles are not equal, the reading will be too high. If they are apart, more force is needed, if overlapping, less is needed. See figure 8.

Fig 8.

Schematic representation of a variety of appearances of the meniscus rings:

(a) the ideal alignment (b) more force needed (c) too much force used, reduce force (d) move cone upward (e) move cone downward (f) wait for fluorescein to drain

• The probe should be removed from the cornea, the weight reading on the scale noted (in grams or X 10 for mmHg), and the cornea checked for staining. The time of the recording is also noted along with the instrument used. This is essential as very little may be discerned from an isolated reading bearing in mind the cyclical variation in IOP.

• If staining is induced, most epithelial stain will disappear within a matter of several hours but caution by the optometrist should be exercised; if worried, monitor. For significant abrasions it is good practice to flush out residual fluorescein as this will reduce the risk of Pseudomonas infection. Simply hold tissues to the cheek of the patient and squirt in as much sterile saline as felt necessary (3 Minims is typically suitable). In the unlikely event of significant stromal fluorescence, an ophthalmologist might be contacted to ensure no further intervention is needed.
Prolonged contact should be avoided to minimise corneal compromise, but it does allow the practitioner to visualise the ocular pulse, seen as small oscillations of the semicircles relative to each other. Prolonged contact also has the effect of reducing IOP by an ocular massaging process. A reduction in this effect or a marked difference between the ocular pulse in each eye may be indicative of vascular occlusive disease.

The thickness of the cornea may also cause some error as a very thin cornea will produce low IOP readings. A very irregular cornea may make visualisation of the rings difficult but a contact method is probably more accurate in this case than a non-contact method. In cases of extreme corneal vulnerability or where anaesthesia is not advisable, the contact methods may not be first choice.

As with any accurate measuring instrument, regular calibration is necessary and is easily carried out by the practitioner. For the Goldmann this requires the use of a calibration rod which is held in a small screw attachment which in turn inserts into the housing on the side of the instrument. The following needs to be carried out regularly, particularly if the instrument has not been used for a while;

• Set up the Goldmann unit complete with tonometer prism on the slit lamp as if to use it to take a measurement.

• Position the rod and lock so that the central marking on it is in line with that on the holding unit. In this position the rod exerts no force on the prism holder.

• The dial should be gently turned from less than ‘0’ until the head is seen to move forward. The force for this to occur, ideally around 0.1g, should be noted. The force should then be reduced and the force noted when the head moves backward again, ideally -0.1g. The middle of the two readings in this case is 0.

• The same is done for the rod positioned with the second marker in position, the rod being pulled away from the direction of the prism such that 2.1g is needed to move the head forward and 1.9 for it to move back (a 2g averaged reading). The last line on the rod does the same for 6g of force.

• If the rod moves at 0.3g, 2.3g, and 6.3g, then it is still a usable instrument but the operator needs to remember to reduce each reading by 0.3g (or 3mmHg).

• If the rod moves at 0g, 2.3g and 6.6g, then there is clearly a stretched spring and the instrument should not be used.

**Perkins contact tonometer**

This instrument was developed as a hand-held, and therefore portable, version of the Goldmann. Having its own light source and viewing lens negates the need for the slit lamp (see figure 9). The probe is held on a counterbalanced mounting with a coiled spring that allows the instrument to be used accurately in either the horizontal or vertical position, useful for the supine patient in a domiciliary visit. This mechanism originally required a slightly differently weighted probe to maintain accuracy, denoted by a red ring marking as opposed to the black ring marking on Goldmann probes. The advent of newer designs of both instrument and probe has done away with this discrepancy.

Fig 9.
The instrument has a headrest attachment that may be extended and held in position on the patients’ forehead to minimise instrument shake, possibly one of the main problems with this instrument. The Mark II version now available has 2 light sources for ease of viewing and may be fitted with a magnifying device (the Perkins Examination Telescope) allowing viewing of the rings at arm’s length. The technique is similar to Goldmann but with a number of variations.

- Patient and prism preparation is the same as for the Goldmann. The patient should be positioned with their head against a head rest to minimise movement and at a height that the practitioner is comfortable with. Too awkward a position when bending and there is a tendency towards shaking.

- It is essential to set the force at the level expected in the eye, based on a previous reading or on a non-contact reading if already available. This minimises instrument adjustment on eye which is more likely to cause staining with the Perkins.

- The forehead rest (if used; some practitioners prefer to remove this and use their hand as fulcrum) needs to be set at a length individually for each patient such that, when pivoted about the forehead, the prism will meet the cornea flat on. For deep set eyes, the arm needs to be shorter and vice versa for more protruding eyes.

- It is as important to be as close to the viewing position for ring interpretation as possible before applanating. Large movements towards the eyepiece while on the cornea invariably leads to the prism drifting off the cornea or at least moving about more than desired.

- Once the rings are viewed, unless very close to their final alignment, it is usually best practice to withdraw from the cornea, make the necessary adjustment, and then return. Avoid undue time on the cornea with the Perkins.

As already stated, Tonosafe probes may be used with this instrument. Calibration should be carried out regularly and may be done by the practitioner. It is similar to the Goldmann technique in that it relies on the use of 3 artificial forces, in this case supplied by weights.

- The instrument should be fitted with a prism and laid on its back, prism upwards. Ensure that the force is vertically applied, some authorities suggest placing the supplied black disc beneath the head of the instrument (or the metal cylinder for the older Mark 1 instrument) having first removed the battery pack from the handle.

- The prism should first pop up just after 0g is set and back down just under 0g.

- A 2g and a 5g weight should in turn be balanced on the prism (obviously rendering it non-sterile and unusable) and the force needed to pop up and down the prism should be just over and under 2 and 5g respectively. Constant error may be adjusted in the final reading, whereas a non-linear error means the instrument is unusable.

- As with the Goldmann, a good examination of the cornea is important subsequent to the technique but in situations where this is not possible (Perkins is often used in domiciliary settings for instance) then a gross view should be used and acuity taken. Advice should be given about reporting any symptoms of discomfort or blur.

Not surprisingly, the results gained are comparable to the Goldmann.

**Tonopen XL mentor**

This is a small, portable electronic contact tonometer which has a stainless steel probe which, on contact with the cornea, measures IOP by an electronic signal from a solid-state strain gauge held within. The short contact time requires several readings to be taken and averaged but this, combined with its small appearance, appears to make it patient friendly.

Results appear to be reliable in comparison with the Goldmann, albeit with some greater spread as may be expected in any instrument taking a series of instant readings compared with one prolonged reading.

**Non-contact tonometers (NCT’s)**

The NCT was first introduced in 1972 and has the obvious advantage of not requiring contact with the cornea. This minimises the potential for corneal compromise, negates the need for anaesthesia, and in many cases is preferred by the patient. Automation of the mechanism means that the instruments are often used by non-professional staff as a screening instrument.

There are a wide variety of instruments on the market, and rarely a year goes by without some new upgrade of an instrument. The basic operation of the instrument relies upon the applanation of an area of cornea by a jet of air which
is usually switched on and off at a point dictated by the quality of image of reflected light from a source on the tonometer. The instrument then electronically converts either the time taken to flatten the cornea or the pressure of air needed into a reading of intraocular pressure.

Because the instruments rely upon the flattened cornea acting to reflect incident light into a receiver, anything compromising the reflection (such as heavy scarring or distortion) will impact upon the accuracy of the reading. However, most designs include an ‘override’ feature allowing a reading to be made even if the received light beam is not maximal. This is also useful if the patient has poor fixation or rapid blinking.

As all the NCT’s take an instantaneous reading of IOP, there is some variation between readings. If the reading is taken on the peak of the ocular pulse, respiratory cycle and immediately after a blink then a disproportionately high reading may be found. It is standard practice, therefore, for the NCT to take 3 or 4 consistent readings before arriving at a useful value. Most instruments automatically calculate an average. A recent innovation has been to incorporate into the patient forehead rest a sensor which monitors the patient pulse. The thinking behind this is to only allow a reading to be taken at a specified point on the cardiac cycle so overcoming any variation due to the ocular pulse. It does not, however, have influence over the other physiological variations mentioned earlier so the days of a ‘single puff’ NCT are not here yet.

The overall perception of NCT’s giving higher readings is likely to be based on practitioners using an inappropriate average or not taking enough readings. In fact any significant studies have suggested if there is any difference it is the NCT being lower than the contact method.

There is now a substantial body of literature comparing results taken from the various NCT’s with the Goldmann standard, certainly within the non-hypertensive population. At higher readings, say above 28mmHg, the correlation breaks down and NCT readings seem less consistent, despite most incorporating adjustments to deal with higher values. It is for this reason, which is becoming increasingly debatable, that many ophthalmologists recommend referral of consistently measured high IOP taken with a contact method, or that high NCT readings be confirmed with a contact method before referral.

There are many NCT’s available, a full description of each being outside the scope of this book. Most incorporate a calibration mechanism and a demonstration setting to allow the patient to know what to expect from the “ puff of air”. This action usually also serves to clear any dust particles from the air chamber which could otherwise be transferred to the patients cornea. Most use a flashing non-accommodative target to reduce the variation due to accommodation and wandering fixation.

**Corneal hysteresis**

As already stated, the deformation of the cornea due to an applied force is, to a certain extent, related to the corneal thickness as well as the IOP within. The deformation is visco-elastic rather than truly elastic, meaning that the recovery of the cornea to its original shape when the deforming force is reduced will occur at a different rate to the original deformation. This is measurable if the force to cause applanation is measured and the cornea further deformed to a concave shape before the force is reduced and that at which the applanated position is reached again also measured. The difference between these two forces represents what is known as the corneal hysteresis and may be used to indicate the resistance of the cornea to force and so to adapt a tonometer reading. An instrument, such as the Reichert Ocular Response Analyzer, attempts this and clinical trials will soon show the validity of such a measurement in predicting actual IOP.

**Ocular blood flow tonometry**

It has already been suggested that that is a close correlation between the IOP and the ocular blood flow. Over recent years a contact tonometer has been developed, the Ocular Blood Flow Tonometer, which measures IOP, and the ocular pulse in terms of pulse amplitude, pulse volume and pulsatile blood flow. In contact with the eye, the machine samples over 200 readings in a second over a period of 7-10 seconds so allowing for several beats of the heart.

As well as providing accurate IOP information, the data regarding haemodynamics provides useful baseline data allowing for interpersonal comparison and changes over time to be analysed. At present, such measurements are rarely carried out outside specialist clinics.

**Analysis of results**

It would be a very easy, if possibly boring, world if it were possible to have a list of situations which would warrant referral, including a cut-off IOP measurement. It should now be clear that IOP alone as a predictor of eye disease is not reliable and that referral in the absence of any other risk factor is only agreed to be necessary at consistently very high values.
A safe policy is for the optometrist to find out what local hospital policy is regarding referral on IOP alone. In the practices this author works in, local ophthalmologists are happy to see patients with repeatable IOP readings of over 25mmHg, and consider treatment if verified to be over 30mmHg. It is not unheard of for the patients in the 25-30mmHg group to be checked and discharged with advice to attend regularly at the optometric practice for IOP monitoring. Many surgeons now treat ocular hypertension of 25mmHg or more with hypotensive agents in the absence of any signs of glaucoma, particularly in high risk groups such as Afro-Caribbeans. This is in the light of the Ocular Hypertension Treatment Studies suggesting such action reduces significantly the risk of any progression in such patients to glaucoma. A very high IOP reading in an asymptomatic eye may occasionally occur in chronic secondary glaucoma conditions, such as Posner-Schlossman syndrome, where the history of inflammatory activity may be vague and the IOP rise only transient.

It is also a significant finding if there is a significant and repeatable difference between the IOP’s of each eye (5mmHg or more), if this finding cannot be related to previous history, such as intraocular surgery, or a significant anisometropia.

As already stated, an unusually low IOP (less than 8mmHg for example) may be clinically significant.

The key points to remember are repeatability and that the IOP fluctuates. A repeatable reading of 26mmHg is significant. It may be that this is the peak of a cycle averaged at around 23.5mmHg and this may be less significant. Interpretation needs to be set against repeated readings as well as all the other risk factors known to influence glaucomatous progression.
Chapter 4

**Slit-lamp Biomicroscopy**

The modern slit lamp biomicroscope consists of two major components: the observation (a compound binocular microscope) and the illumination systems. The observation systems of most modern instruments have a magnification range between 5 and 40x. Whereas a high magnification would seem desirable, its use often compromises the overall image quality (resolution).

The illumination system of a modern slit lamp projects a uniform bright image of a slit onto the plane of focus. The ability of a system to project a very sharp, very thin and non-distorted slit is crucial to obtaining a true representation of the ocular structures.

The normal white emission of the slit lamp can be modified with the introduction of filters in the path of the beam. The normal filters incorporated in an illumination system are:

- Diffusing filter. These disperse light over a wide area allowing the observer to illuminate a wide width of the object under investigation. When used in conjunction with low magnification it is particularly useful in giving a good overview of the eye and its adnexa.

- Cobalt blue filter. This works by altering the emitted light so that the resultant beam is blue. It is most commonly used in conjunction with a fluorescein stain and particularly in contact lens work, where a yellow Wrattan filter may also be used to enhance areas of staining (figure 1).

Fig 1.

![Use of Wratten filter enhances staining](image)

- Red-Free filter. This filter produces results in the emitted beam being green. The result is that red objects are enhanced, appearing a much darker colour. As a result these filters are frequently used to enhance blood vessels, particularly the limbal arcades (loops) or new vessels that are often very difficult to see particularly when these fine-calibre vessels are devoid of blood.

- Heat reducing filters. These absorb light at the red end of the spectrum that are capable of causing thermal damage. These are particularly useful for long examinations as they enhance patient comfort and are strongly recommended for extended fundus assessment.
• Neutral density filters. These have largely been replaced in modern instruments by a rheostat control. These filters are a very crude way of controlling the amount of ambient illumination.

• Polarisating filters. These can be used to reduce the amount of glare and can be useful in techniques such as specular reflection.

**Set up**

It is essential that both the practitioner and patient are comfortable throughout the examination procedure. The parts of the instrument in contact with the patient should be sterile for each patient (this author prefers isopropyl alcohol wipes of chin and forehead rests rather than replaceable paper contact sheets) and the patient chair correctly elevated such that the patient is not bending or stretching to maintain forehead contact with the rest. The canthus mark on the headrest should be in line with the patient outer canthus (though again this author recommends checking the vertical run of the instrument runs clear above and below the palpebral area).

In normal usage the observation and illumination systems have a common centre of rotation and it is this that allows sections of transparent material to be viewed in detail at high magnification. Prior to using the slit lamp (on a daily basis) it is generally recommended that the slit lamp eyepieces are focussed. Failure to do so is the most likely reason why high magnification images are not distinct. This is achieved by placing a focussing rod in the hole of the central pivot. A focussed slit will appear on the rod and the eyepieces are adjusted individually so that the grainy appearance of the rod is clearly visible through each eyepiece. This procedure is performed firstly at low and then high magnification in order to maximise accuracy.

Where a focussing rod is unavailable, the best option then is to focus eyepieces on as flat an area directly over the hole into which the rod is placed. The patient’s forehead may suffice and the correct positioning of the illumination is known when there is no movement of a slit beam projected onto the area when the angle of the illumination system is altered. Focussing the eyepieces at this point will again ensure a common centre of rotation.

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**Examination techniques**

Each examination technique is as individual as the practitioner utilising it. There can be no prescriptive guidelines on the use of this instrument. In the following section a general slit lamp routine is discussed highlighting five recognised techniques are: diffuse illumination, sclerotic scatter, direct illumination, specular reflection and retro-illumination. There will then be some more specific clinical examples of technique specific to different patient presentations.

**Diffuse illumination**

This is generally utilised when an overview of the ocular surface and adnexa is required, but is also useful for photography of structures anterior to the iris when a point reflection wants to be avoided (figure 2). A simple way of performing this technique is to use a broad beam on mid-rheostat setting and scan across the eye in a zigzag pattern. The angle between the observation and illumination systems is kept such that incident light is kept perpendicular to the surface of regard to ensure a good yet even illumination. A mid palpebral sweep from outer to inner canthus would reveal bubbling in tears, obvious bulbar conjunctival and corneal lesions, punctal and inner canthal anomalies. Asking the patient to look upward, the lower lid may be pulled downward while the lower third may be viewed with particular regard for the lower palpebral conjunctiva and the lid margin and lashes. Asking the patient to look down, the upper third sweep may be done again with the lid lifted (and everted if required).

Many instruments have an easily introduced diffuser filter which, if used in conjunction with a full rheostat setting, gives optimal diffuse illumination. Older instruments produce this on the reverse of the mirror though reversing the mirror in practice is often cumbersome (as is the sometimes quoted placement of a tissue in front of the mirror to act as a diffuser).

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Fig 2.
Diffuse illumination

Sclerotic scatter
The basic principle of this illumination technique is total internal reflection of light through the cornea. A narrow beam is focussed at the temporal edge of the limbus at an angle of around 45 to 60º to the corneal apex. The beam is kept 1 to 2mm and its height is kept between 4 and 6mm to avoid producing glare off the sclera. As the light enters through the limbal junction total internal reflection occurs within the cornea and emerges at the opposite limbal junction. The resultant image produced by the total internal reflection resembles a halo around the cornea. If there is a change in the local refractive index of the cornea light is scattered from this region. This scatter will cause the image to appear bright against a relatively dull background. Some authorities advocate viewing sclerotic scatter with the naked eye from the side, rather than using the microscope, as looking through the microscope could result in the viewer looking at the apex of the cornea, while its focus lies in the plane of the limbus. However, at low magnification it can be argued that the depth of focus should be low enough to allow both areas to be viewed. If higher magnification is required in this technique then uncoupling of the instrument will be required. In this case the central cornea should be focussed upon and then the light decoupled and moved to shine at the limbus. The technique shows up areas of corneal compromise as with oedema, which will show as a general glow from the oedematous area, or corneal penetration, showing as a pinprick of light at the impact point.

Direct illumination
As its name implies this technique allows the clinician to illuminate the object of interest with the slit beam and observe it under magnification with the observation system. A complimentary adjunct of this technique is indirect illumination. More often than not the practitioner utilises these techniques in tandem without being aware of it. With the former high contrast objects are readily visible and with the latter low contrast entities are often visible. Corneal lesions, for example, are readily visible with direct illumination, but scars may be more easily viewed with indirect illumination, assuming that the field of view is large enough.

Corneal and lens sections are best viewed with direct focal illumination (figure 3 and 4). The slit needs to be as thin as possible and the rheostat on maximum to achieve best detail. For corneal sections, the wider the angle between microscope and illumination system, the wider the ‘slice’ of cornea viewed.

For the lens, the angle is to some extent dictated by the pupil size. A dilated pupil should allow for a much wider angle to view a larger ‘slice’, while for a miosis the angle of the slit lamp parts may have to be small if a decent section depth is to be achieved. Whereas all the layers of the cornea may be visible in section at high magnification slight focussing movements may be required to view its respective layers. However, with the lens it is unlikely that all the layers will ever be visible in one position. In order to maximise the area viewed the separation angle needs to be kept small and low magnification would give a better field of view. The height of the beam is normally restricted to the height of the pupil to allow the maximum amount of light to enter through to the lens (avoiding pupil constriction) and fine focussing movements will allow the different layers of the lens section to be viewed. As the lens is viewed from its anterior to posterior surface the angle of separation is reduced accordingly.

It is sometimes desirable to gain a 3D view of the cornea (or lens, although less useful). It is particularly useful when scanning the cornea or lens. This is achieved by widening the beam width once a good section has been obtained. Whereas this results in a loss of clarity of the layers, the resultant parallelopiped allows the clinician to form an
opinion about the depth of any interesting feature. By then narrowing the beam the observer can then make a more accurate assessment of the depth.

Fig 3.

[Image: Corneal section]

Fig 4.

[Image: Lens section]

Conical beam and section

This useful adjunct of direct illumination is used to check for flare and cells that may be associated with an anterior uveitis. It is not too dissimilar to forming a section but the broader and shorter. When the ambient light is as low as possible (ideally a pitch black room) the cone of light is directed into the anterior segment. A circular aperture is preferred to perform this technique. The beam is focussed in the anterior chamber, which means that in a coupled instrument the microscope should also focus on the same plane. If the magnification is kept low enough the entire anterior chamber should be in focus.

A bright reflex is seen off the corneal surface and less bright one off the lens surface. Normally the area between the two reflexes is empty and so appears dark, but when inflammatory material is present light is scattered giving this normally optically empty space an appearance similar to that seen in the beam of a cinema projector. The scatter caused by the particles is known as Tyndall’s phenomena. It is worth noting the difference between cells and flare. Flare is dissolved protein in the aqueous and will be seen as a continuous beam between the corneal reflex and the lens reflex.
Flare present or not should be noted. Cells are inflammatory cells that glitter as they pass through the beam. These, if present, can be counted. This author prefers to note how many cells are seen in 10 seconds. Also, don’t forget it is useful to look for cells and flare when assessing corneal lesions. Their presence may well be one of the first signs of microbial keratitis in an otherwise innocuous looking corneal lesion.

**Specular reflection**

When a corneal section is formed on the same side as the illuminating system a bright reflex is often visible through the observation system. This can often be a hindrance as it tends to be superimposed upon the corneal section. What the clinician is observing are in fact the first and second Purkinje images. The image on the epithelial side tends to be brighter and is a direct reflection of the bright white light of the bulb, whereas the image on the endothelial side tends to be a less bright golden colour. Due to the positioning of the illumination system the images are only visible through one of the eyepieces of the observation system.

Specular reflection is the preferred choice of illumination for observing the corneal endothelium. In its simplest definition, specular reflection is the bouncing of light of a flat surface to reveal details of the surface. In order to achieve a good view the slit beam is normally shortened and widened. To achieve the best view of the endothelium high magnification should be used, typically in the order of 40x (Figure 5). At such a high magnification slight adjustments to the focussing of the instrument are required. Additionally slight adjustment of the illuminating system may also be required to optimise the image.

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**Fig 5.** Specular reflection used to view the endothelium at 40x magnification

Surfaces such as the corneal endothelium are visible by specular reflection as they are not perfectly smooth. Light is reflected at various angles, which allows the ‘roughness’ of the surface to be assessed. Light that is not reflected back towards the microscope appears dark whereas that which is appears light.

**Retro-illumination**

Viewing certain ocular structures with direct illumination sometimes poses difficulty, either as a result of their proximity or as a result of their structure. Take for example the limbal vasculature, its close proximity to the corneoscleral junction often results in excessive glare from the sclera when viewed in direct illumination (Figure 6). In direct illumination is often more beneficial however the relative lack of illumination often make these fine vessels difficult to see. Another example is corneal nerves, which are notoriously difficult to see as they enter the cornea beyond the limbus. In both examples these structures are best viewed by illuminating them from behind rather than directly in front.

As the name indicates retro-illumination involves illuminating the object of interest from behind. The reflective nature of some of the ocular structures is utilised to create a secondary diffuse source of illumination from within the eye. A good example of retro illumination that most practitioners have experienced of is the dark appearance of a cataract seen against the red-reflex generated by a retinoscope. In a slit lamp examination the diffuse reflector is often the iris. It is a popular misconception that when performing retro illumination the slit lamp has to be decoupled. It is only necessary when the corneal apex is being viewed, the separation angle is too large, high magnification is used and the
beam is narrow. For small separation angles and areas close to the limbus the cornea (or associated structures) can be viewed without uncoupling (see figure 6). If, however, one wanted to look for microcysts in the central corneal area then an area of cornea in front of the pupil margin may be focussed on. At this point, the illuminated iris part will not be directly behind because of the larger distance between the cornea and iris here. The light on the iris may then be carefully moved until behind this position by decoupling and then the microcysts be viewed (figure 7).

Fig 6.

Retro illumination used to highlight limbal blood vessels

Fig 7.

Decoupling is only required at high magnification

General examination of the eye
In the absence of any specific symptoms the slit lamp examination of the eye can be thought of, in the broadest terms, as a two-step procedure. The routine begins with a generalised examination of the eye and then continues using advanced examination techniques, with a more detailed examination of the ocular structures. Although the slit lamp is the principle instrument for examination of the eye in a contact lens wearer for the purpose of this chapter we will assume the eye under observation belongs to a non-lens wearer, although where particularly relevant reference will be made to differences between the two types of eye.

In most general examinations it is customary to begin at the front of the eye and move deeper-in to examine the finer ocular structures. As such, it is normal to begin with an examination of the eyelids, tear-film and conjunctiva. Observing these structures is generally best-performed using diffuse and direct illumination together with low magnification, but if an object of particular interest is seen, then higher magnification is frequently be utilised.
Examination of the eyelids
A large angle between the illumination and observation systems and diffuse illumination together with low magnification offer the best setup for a general examination of the surface of the eyelid. This allows the clinician to assess the eyelid position, examine for ptosis and check for any lid lumps or bumps.

Examination of the tear film
The tear film is arguably the most under examined ocular structure during a general examination of the ocular surface. Many symptoms of ocular discomfort or asthenopia can be attributed to deficiencies in the tear layer. The tear film is essentially a tri-laminar structure consisting of: a mucin layer (closest to the cornea), an aqueous layer and a lipid layer (closest to the surface). Anomaly of any of these layers can result in the patient experiencing symptoms. It is normal for the tear film to be examined following the instillation of sodium fluorescein in blue light (produced by the cobalt blue filter), however, with the reduction in the amount of ambient light produced by this technique some subtle changes to the tear film may be missed.

Diffuse illumination and low magnification offer a good overview of the tear film. This allows the clinician to observe any debris in the layer. Direct illumination or an optical section can then be utilised to investigate detail. Debris in the tear film often appears as particles and can be indicative of blepharitis.

The tear prism can be seen by direct illumination. This is typically 0.2 to 0.5mm high in the centre and tapers off to approximately half this height in the periphery. A known height (or width) of slit may be superimposed over the prism allowing an accurate measurement to be made.

Instilling fluorescein is an invasive method of assessing the tear film. Prism height measurement may be attempted without fluorescein first. Similarly, break up time before instillation may be attempted by assessing the time taken for a reflection from the tear film to become distorted.

Excessive tearing is a hindrance to the patient and is of course clinically relevant. However, insufficient tears tend to give rise to more symptoms and signs. A depleted tear film may give an indication of a tear layer deficiency. Clinicians regularly determine the tear break-up time (TBUT) once fluorescein has been instilled, a procedure familiar to most readers. The eye is illuminated with a broad beam and the cobalt blue filter is in place. Low magnification is used. The patient is asked to blink normally a few times and then ask not to blink. The time taken for dark spots or streaks to appear is noted (figure 8). This indicates a break-up of the tear layer. Normally, this would take 15-20 seconds, any figure below 10 seconds is deemed to be abnormal and indicative of a dry eye. Where the same area consistently breaks-up rapidly, there is likely to be a surface irregularity rather than a dry eye. The clinician should investigate this further using direct illumination, optical section and high magnification.

Fig 8.

Tear break up time
Examination of the conjunctiva
As with the lids and tear film, the best way to obtain a general view of the conjunctiva is to use diffuse illumination and a low magnification. Dyes, filters and stains (lissamine green for dry eye states) all help in the investigation of any anomaly seen in addition direct, focal illumination and higher magnification will allow more accurate diagnosis of the problem.

For ease of description between fellow practitioners the conjunctiva can be sub-divided into zones. Although useful, a far simpler technique is to indicate any areas of interest on a diagram, particularly as there seems to be a lack of standardisation between the various systems that exist. The degree of redness can be determined by comparing the clinical observations to a pictorial grading scale.

Everting the eyelids to expose the conjunctiva in this zone is essential if follicles or papillae are suspected (figure 9).

Fig 9.

Eyelid eversion

Specific examination of the anterior segment structures
Following a general examination of the ocular surface and adnexa it is desirable to utilise all of the varied illumination techniques to assess some of the finer structures of the anterior segment. These include the cornea, anterior chamber, iris and pupil, lens and the anterior vitreous body. This may be as a part of the routine examination or as a result of specific symptoms reported by the patient.

Examination of the cornea
For the initial examination of the cornea the illumination system should be set at an angle of 45 to 60° from the observation system and a relatively wide beam should be used in order to create a relatively thick section or parallelopped. It is possible then to scan the cornea in 3 zones: the superior, middle and lower regions. Using focal, direct (and indirect) illumination allows the clinician to pick up any lesion, which can then be investigated in greater detail using other illumination techniques. Staining the cornea with fluorescein and observing any areas of pooling is also considered an integral part of any routine.

If a lesion is found on the cornea there are a number of factors that need to be determined before the appropriate course of management can be initiated. These include its location, size, density, colour and depth. The size of a lesion can be determined using the height of the beam as a measuring device. The best way to observe the depth of a corneal lesion is to observe it in a thin optical section. The following three sections are particularly relevant to corneal examination of the contact lens wearer but are deemed essential to a thorough slit lamp investigation of the cornea.

Corneal vascularisation
New vessels are often present in the cornea of long-standing soft contact lens wearers. These are usually most in the upper cornea, under the top lid. To the inexperienced microscopist they can be difficult to distinguish from the normal conjunctival overlay of the cornea that exists in this region. New vessels are generally finer and unlike the normal limbal vascular arcades form tight hairpin loops. They are best visualised with an angled beam and a combination of
direct, indirect and retro illumination. Using a red-free filter may also enhance the vessel appearance. Ghost vessels (or previously perfused new vessels) are best seen with indirect or retro-illumination.

**Microcysts**
Microcysts are only visible at magnifications of 25x and greater and are only identifiable at magnifications around 40x. They are best examined using a modified technique known as marginal retroillumination.

**Corneal endothelium**
Setting the slit lamp for specular reflection and utilising the Purkinje images is the best way to view the endothelium.

**Examination of the anterior chamber**
There are two principal reasons to examine the anterior chamber:

• To assess for the risk of angle-closure glaucoma; and

• To assess for any particles

Perhaps the best-known method of assessing the anterior chamber depth is the Van Herick technique. This is discussed in detail in another chapter. Other methods of assessment of the anterior chamber depth do exist. If performed correctly this technique can be very effective but is not completely without flaw, for example, an anterior chamber can appear shallow using the Van Herick technique, thus leading to suspicions of risk of angle-closure glaucoma, but gonioscopy could reveal that there is little or no risk at all.

A typical procedure for performing a Van Herick technique is as follows.

• The patient is asked to look straight ahead towards the microscope and the illumination is set at 60° temporal to the eye under investigation. Setting the angle always at 60° ensures consistency whenever this technique is used and allows results to be compared between observers.

• The microscope magnification is kept relatively low to around 10 to 16x thus giving a good depth of focus

• The slit width is reduced to a minimum in order to create an optical section of the cornea as close to the limbus as possible. Reducing the slit width normally will involve having to increase the lamp intensity.

• A comparison is made between the thickness of the cornea and the gap between the posterior corneal surface and the iris (figure 10). The ratio of these two may be graded and interpreted. This author prefers a decimal system now as more accurate. So if the black gap is about a half the corneal section thickness, note 0.5. If just under the thickness, note 0.9. Note how, under the original grading system both would have been noted as grade 3.

• The measurement is repeated for the nasal limbal area. If there is a large difference between the two measurements the narrower measurement is considered.

Fig 10.
Van Herick technique
Examination of the anterior chamber for inflammatory cells or flare should be made using the conical beam technique described earlier in this chapter. It is worth noting that low-grade flare can be a subtle sign which is easily missed (figure 11). The technique should be carried out in near darkness with all room lights off and the beam should be directed through the pupil to avoid light scatter from the iris. Obtaining a good angle between the illumination and viewing systems may mean moving the viewing system off to one side.

Fig 11.

Flare and cells in the anterior chamber

Examination of the iris and pupil
For the inexperienced clinician the iris is a fascinating area to observe with a slit lamp biomicroscope. The crypts, pigment ruff and vasculature are all readily visible with direct, focal illumination, with the angle of illumination set between 20 and 30° and a moderate beam width and magnification.

Examination of the lens
The lens is best observed using a combination of direct, focal and retro-illumination. With the former illumination technique a thin paralleloped or section reveals the multiple layers of the lens, rather like the layers of an onion.

Retro-illumination used to investigate the lens can also be demonstrated with a retinoscope or an ophthalmoscope. The slit lamp technique involves the same principle – observing any defect illuminated from behind by light reflected from the retina. The microscope is placed in the straight-ahead position with the lamp nearly coaxial (but allowing binocular viewing). The microscope is then focussed on the object under consideration; the beam is then decoupled and swung so that it enters the pupil near the margin. The beam should be around 4mm in width and the height is adjusted to avoid any unnecessary reflections from the iris. Retro-illumination is particularly useful in observing cortical cataract.

Examination of the anterior vitreous
Examination of the anterior vitreous is difficult as the overlying structures cause scatter thus interfering with the final image produced. Direct focusing of a lens section towards the rear of the lens and then look carefully into the space immediately behind the lens. Asking the patient to move their eye up and then forward again may help in seeing any material here. White ‘wisps’ are generally vitreous material of no concern whereas particulate matter, possibly pigment or cells, needs explanation and may indicate a peripheral retinal tear so requiring referral (Shafer's sign – figure 12).

Fig 12
Shafer’s sign (tobacco dust)

Further reading
The investigation of visual fields is an essential component of any eye examination as it is able to detect early ocular and neurological disease processes which other investigations may miss.

The extent of the absolute visual field is dependent upon the shape of the head of the patient, but it is important to remember that the extent of the temporal field is almost always greater than 90 degrees. Typical values are 100 degrees temporally, 75 degrees inferiorly, and 60 degrees nasally and superiorly. The last two are most patient dependent because of variable nose and brow size.

Binocularly, the two monocular visual fields overlap, resulting in a stereoscopic zone which is approximately 120 degrees in the horizontal dimension. The extreme temporal periphery of the binocular field is seen monocularly. (figure 1)

Binocular field

The retinal image of the visual field is upside down and back to front. Therefore, the projection of the visual field is such that the superior visual field corresponds to the inferior retina and vice versa. Similarly, the temporal component of the visual field corresponds to the nasal retina and vice versa.

Static or kinetic

It is well understood that the retinal sensitivity to any target decreases the further away from the fovea the image falls. This was classically described by Traquair as representing a hill of vision whose peak corresponded to the fovea and whose slopes represented the gradual reduction in sensitivity towards the periphery of the retina until ‘the sea of blindness’ is reached; the point beyond which no target presented will be seen.

Kinetic perimetry involves the movement of a constant sized target from beyond the field of vision to the point where it is just seen. The larger target should be seen closer to the extent of the absolute field, the smaller target further to the centre of the field. In this way, kinetic perimetry may define the ‘hill of vision’ by the use of variously sized targets moved to the point of identification. Generally, kinetic perimetry is primarily used in optometric practice as a gross assessment of the visual field when a quick test is needed to detect a major scotoma or the cause of a constricted field.

Static perimetry employs the use of a target or targets (multiple stimulus or tachistoscopic presentation) of increasing intensity presented to the same point or points within a field until the intensity is reached at which the target is just seen. The majority of automated central visual field screeners employ multiple static stimulus presentation as it is more repeatable, often quicker, and more useful for defining a more subtle scotoma - allowing for the depth of a partial or relative scotoma to be measured. Less controlled, gross variations of static perimetry are also useful, such as some of the confrontation tests used in neurology or the Amsler grid.

Confrontation

Though the terms confrontation and gross perimetry are often used as synonyms, strictly speaking confrontation describes one of several “comparison” tests whereas gross perimetry is the use of a target to measure the extent of the visual field and to map any large scotomas within the field. One form of confrontation involves the use of a target
moved along an imaginary flat plane between and perpendicular to the gaze of the patient and the practitioner. This obviously will not allow the temporal extent of field to be measured, but will allow the practitioner to confirm that any areas they see can also be seen by the patient. One could also describe other tests as confrontation tests, for example, the presentation of two red targets to the hemifields of the patient to find out whether one of the targets is desaturated, or the use of a shiny coin in four quadrants of the field of one eye. Many confrontation tests are used by neurologists in investigating possible neurological lesions.

**Gross perimetry**

Gross perimetry describes the use of a handheld target held at a constant distance from the patient’s eye which, when brought in an arc from beyond their visual field boundary, allows them to announce when the target is first seen (the extent of field or boundary for that particular target size and colour). Continuing the movement of the target through the visual field to the central point of fixation allows any large defect to be detected.

The choice of target dictates the extent of the isopter, just as with any kinetic assessment. A larger target will be seen at a greater eccentricity, while the isopter for a small target will be contracted. Similarly, a white target brought from beyond the field will be seen before a red target which will itself be seen before a green target, the reduction in sensitivity being related to the lower luminance of the coloured target compared to a white target. In practice, although a small white target might be justifiable in terms of sensitivity, a red target is generally chosen as it will contrast better with typical wall coverings within the consulting room. To maintain some degree of correlation with a 5mm white target (typical for gross perimetry), a 15mm diameter red target may be used instead, its extra size counteracting the reduced sensitivity to red compared to white.

**The Amsler chart**

The Amsler chart represents a simple method of assessing the quality of the central field of vision. The test includes several charts, the basic and most commonly used being a square white grid printed on a matt black background comprising twenty rows and twenty columns of smaller squares (figure 2).

![Amsler recording chart](image)

**Amsler recording chart**

When viewed at 28cm, each square subtends one degree at the retina. The grid therefore is used to assess the field ten degrees either side of the fixation point when viewed monocularly (as should always be the case). It is possible to map out the physiological blind spot by directing the patient to view the nasal edge of the grid such that the blind spot 15 degrees temporal to this point falls onto the grid. Though rarely done, it is (at least in theory) possible to detect blind spot extension in, for example, myelinated nerve fibres around the disc or in early papilloedema. Typically, however, the grid is used to assess macular function.

Indications for its use include the following;
• Evidence of macular disturbance seen on ophthalmoscopy in either eye (if seen in just one eye, both eyes require investigation because of the bilateral nature of most macular diseases)

• Unexplainable loss of central visual acuity

• Reduction of acuity through a pinhole

• Symptoms of central visual disturbance, such as distortion

• History of systemic disease or more commonly drugs which may predispose to a maculopathy (such as tamoxifen or chloroquine). For the assessment of possible early toxic maculopathy, the red Amsler grid may be slightly more sensitive

• For the mapping of a central scotoma already detected. This is useful for monitoring any progression of a scotoma. For this assessment, the grid with diagonal cross lines is useful to encourage stable fixation. The patient should be asked to fixate upon the point where they imagine the centre of the cross to be. In cases of poor performance with magnification, noting the position of the scotoma relative to the centre is useful. A scotoma shifted towards the right of the field will have a greater impact upon the ability to scan from left to right when reading.

• History of poor photo stress recovery. Reports of persistent after images after exposure to, for example, a flashlight or a difficulty in adapting to changes in ambient light levels may indicate early macular disease. A simple procedure might be as follows;

• Correct the patient to adequately see the target at 28cm. Illumination should be good without constituting a glare source, and one eye should be occluded.

• The patient should be directed to fixate upon the dot in the centre of the grid. As poor fixation is perhaps the main source of error in any field assessment, this instruction cannot be repeated enough throughout the test

• While looking at the central target, the patient should report if any of the four corners of the grid are missing and, if so, the missing area should be shaded on the record sheet (a replica grid only in black on a white background)

• The patient should then report if any of the grid is missing and, if so, the position and size of the blind spot noted

• The patient should then report if any of the lines are wavy or distorted and again this recorded if found. If distorted, it is useful to note if the distortion is static (as might be the case with an old atrophic scar or a heavy concentration of drusen around the fovea) or moving or shimmering. The latter, described as metamorphopsia, might be indicative of an active exudative process (such as prior to choroidal neovascularisation) and might warrant an urgent referral.

In cases where one eye has already suffered macular disease, or where there is evidence of macular disturbance yet to affect vision, many practitioners give a copy of the grid to the patient who may then self-monitor their central field on a regular basis at home and in the knowledge that they must report any new disturbance they might detect.

**Sensitivity versus specificity**

So far, the assessments considered have been fairly crude. Their ability to detect minor changes in the field of vision are limited (so have a low sensitivity). On the other hand, any defect detected is likely to be actual and related to an abnormal process (so their specificity is high). The balance of the ability of a test to correctly identify disease (sensitivity) while on the other hand ensuring that patients free of disease do not fail the test (specificity) is an important one for fields assessment and the relationship between the two may be changed according to the desired outcome. An bright target should be seen by all normally sighted people and only those with a significant defect will miss it. A test using a bright target would have maximum (100%) specificity. On the other hand, the test would have low sensitivity because even those patients with a mild field defect would still report seeing the light and many early disease presentations would be missed.

The highest sensitivity would be gained by using stimuli of an intensity just visible to the point of the retina to which it is presented and which would not be seen if of a lower intensity. This form of presentation is described as a full threshold assessment as it employs stimuli of an intensity set at the threshold of the retinal ability to detect them. This maximum sensitivity should allow even the mildest partial scotoma to be detected. However, many normals might also struggle to see some of the stimuli and report them as missing. This therefore would represent low specificity. Generally speaking, a screening programme should be sensitive enough to detect most eye disease while specific enough for normals to pass the assessment. A suprathreshold assessment uses stimuli of a set intensity brighter than threshold such that all normals should see them and yet defects of a depth greater than the intensity level above threshold should fail the assessment.
Generally for screening purposes, a suprathreshold assessment is preferred as it is quicker, sensitive enough to detect most defects while allowing most normals to pass. For investigation of a suspicious patient presentation, such as someone with glaucomatous disc appearance or a strong family history of glaucoma, a full threshold assessment, though more demanding of the patient, is more likely to detect even the first evidence of reduced retinal function. Suprathreshold fields are also poor at monitoring the progression of field defects, so in secondary care, full threshold fields are preferred.

Automated fields screeners
Most automated field screeners assess the central field to within 25 to 30 degrees from fixation. Whilst it is true that around 85 per cent of field defects fall within this space, the remaining minority affecting the intermediate and far periphery can be clinically significant. Such defects might result from retinal damage, as with for example chorioretinitis, retinal detachment, a neoplasm or early retinitis pigmentosa. It is also important to remember that many defects due to damage to the visual pathway may also start in the far periphery and only extend into the central field at a later stage. An example might be the superior bitemporal loss due to compression of the chiasma from below by a pituitary adenoma (remember a bitemporal hemianopia does not just suddenly appear and the very first compression will result in far superior bitemporal loss, often asymmetric). A gross perimetry assessment is always worthwhile to support a more accurate automated static central assessment. Alternatively, some screeners, such as the Dicon or the Zeiss Humphrey Visual Field Analyser, allow the practitioner to select a programme which can assess more peripheral fields as well.

Most modern screeners, even suprathreshold screeners such as the Henson, are capable of full threshold testing and can establish the threshold sensitivity at each point to which a stimulus is presented. The Humphrey Visual Field Analyser may be programmed to assess the field faster by incorporating the Swedish Interactive Thresholding Algorithm (SITA). It was designed as an attempt to decrease the time taken for a traditional staircase method assessment (a 4-2dB algorithm typically takes 15 minutes) yet maintaining good sensitivity in glaucoma detection. Test duration is reduced in several ways. The algorithm specifies the appropriate stimulus brightness to be presented at each point, “guessing” the value from the thresholds already established. It also monitors the time taken to respond to a stimulus as an indication of how close the stimulus is to threshold and is able to stop once sufficient information has been taken. The presentation of stimuli at levels around that at which fifty per cent are seen greatly reduces the speed of testing. So by better pacing of the test, and the useful interpretation of false positives and false negatives, the SITA appears to correlate well with standard perimetric assessment yet takes less time. The reduced duration is likely to help accuracy of patient response. Longer does not necessarily mean better with field assessment. Poor compliance, fatigue and loss of fixation all play an increasing part in reducing the accuracy of field assessment. This is one of the reasons why it is essential, if a field defect is suspected, for the test to be repeated to ensure that any defect is not artefactual

Reliability indices
As already stated, one of the major problems with fields assessment is the detection of abnormal data that is due to patient ‘error’. Poor fixation or fatigue can lead to points being reported as seen when they should have been missed (a false positive) and not seen when they should have been (false negative). Many modern screeners, such as the Humphrey VFA or the Oculus, record these errors such that the reliability of a plot might be interpreted by a practitioner. False positives are recorded when a stimulus which has not been shown or has been presented at an intensity known to be below the threshold value for the individual is still reported as seen. A false negative is recorded when a stimulus known to have been previously seen is now missed. Any significant score in the reliability indices (over 20%) is an indication that the assessment needs to be repeated, as the plot cannot be usefully interpreted and acted upon (figure 3).
Reliability Indices

A common method of assessing fixation loss is by using the Heijl-Krakau Technique of monitoring fixation throughout a field assessment by means of projecting a bright stimulus into the blind spot from time to time. If fixation is not present, the patient will respond to this stimulus and the machine will note the number of errors. The technique is open to error as it is only a sampling technique, testing fixation a handful of times during the field test and unless the blind spot is accurately plotted first, the assumed location of the blind spot may be incorrect. Gaze tracking is an alternative which allows a continual assessment of fixation throughout by monitoring the alignment of the Purkinje images from the ocular surfaces. A more erratic gaze tracking plot is an indication of poor fixation.

Total and pattern deviation

Some instruments, notably the Humphrey VFA, incorporate software allowing analysis of any variation in the assessed field. Any threshold value found to be below that expected in an age-matched population will show up as a defect in the total deviation plot. Fogging a twenty-year-old normal patient will reduce their threshold value across the entire field and this will give an extensive total deviation. A similar effect is seen with cataract.

The pattern deviation plot represents significant variation in retinal sensitivity within the field, as might be the case with a scotoma. If a patient has a cataract and also glaucoma, it is possible that they have an extensive total deviation defect while just the earliest signs of an arcuate defect in the pattern deviation plot. In this way, the screener can help to separate out diseases of causing a true visual field anomaly from those causing artefacts, thus increasing its diagnostic value.

Fig 4.

Total & pattern deviation plots

To understand probability plots it is necessary to understand the normal age-related decline in sensitivity which occurs across the visual field. The normal sensitivity of the peripheral visual field declines at a faster rate than centrally, i.e.
the hill of vision changes shape with advancing age, becoming steeper in profile. There is a range in sensitivity, which is wider at more peripheral locations. The 95 per cent confidence interval predicts that 95 per cent of normal values fall within this region. Therefore, if a sensitivity value falls outside this range, it will gain a P<5 per cent probability level, i.e. the sensitivity is normal in less than 5 per cent of the normal population. Thus, probability plots graphically illustrate the level of statistical significance associated with a given visual field abnormality compared with the normal reference field.

As stated, there are two types of probability plots, total deviation and pattern deviation. In the total deviation plot, the difference between the measured visual field sensitivity and the expected normal visual field sensitivity are plotted as a numeric map. A second plot illustrates those locations where the deviation is significantly different from the normal population, either at the P <0.5 per cent, P <1 per cent, P <2 per cent or P <5 per cent levels. The pattern deviation probability map separates the general reduction in sensitivity that may arise through media opacities, optical defocus or pupillary miosis (the total deviation) from any localised reduction in sensitivity. To calculate the pattern deviation probability map, all locations within 24 degrees of fixation are ranked according to the deviation in sensitivity compared to the age-matched normal population. The general height of the hill of vision is calculated from the measured value of the seventh highest deviation (85th percentile) in sensitivity.

The glaucoma hemifield test
The glaucoma hemifield test (GHT) was introduced in the Humphrey field analyser with the aim of deciding whether visual field loss was compatible with a diagnosis of glaucoma. Ten anatomical sectors in the visual field are superimposed on the Program 30-2 test grid, selected according to the normal arrangement of retinal nerve fibres. Five sectors in the upper hemifield mirror five sectors in the inferior field.

Probability scores are calculated for each location within the 10 sectors according to the pattern deviation probability map. Within each sector, the sum of the probability scores is calculated and the difference compared to the mirror image sector. A visual field is classed as ‘outside normal limits’ if the difference in any of the five corresponding pairs of sectors falls outside the 0.5 per cent or 99.5 per cent confidence limits for that pair of sectors. Visual fields are classified as ‘borderline’ if any sector-pair difference exceeds the 3 per cent confidence limit. If the general height of the field is below the 0.5 per cent limit, the GHT evaluates the field as a ‘general reduction in sensitivity’.

A classification of ‘abnormally high sensitivity’ is associated with a high level of false-positive responses. The general height test is not performed if the visual field has already been classified as ‘outside normal limits’. A sensitivity and specificity of 80.8 per cent and 81.4 per cent respectively has been reported for the GHT.

Interpreting field defects
Every field screener produces its own particular plot and interpretation varies depending upon the model. This is covered in much greater detail in the Visual Fields Eye Essentials book by Dr Robert Cubbidge. However, a few general points should be outlined;

- Check the field plot reliability indices first. A high number of fixation losses, false positives or false negatives makes the field plot worthless
- Any repeatable defect needs to be taken seriously but consider possible artefacts (such as lens rim or eyelid) first.
- Overall threshold values between the eyes should be similar. If not, this may indicate reduced light levels reaching the retina, as with media opacification
- Single points of reduced sensitivity close to the disc often represent the obscuration of photoreceptors by an overlying retinal blood vessel (an angioscotoma)
- Defects found in the area between the blind spot and fixation (centrocecal defects) usually are associated with damage to the papillomacular bundle of retinal nerve fibres as can occur with toxic responses to drugs or excessive alcohol consumption
- Field loss in one eye is due to a lesion anterior to the optic chiasma
- Irregular, asymmetric loss in both eyes which does not seem to be limited by the horizontal or vertical midlines is often related to focal retinal damage and can be confirmed by ophthalmoscopy
- Progressive optic neuropathy, such as glaucoma, will tend to affect the arcuate fibres initially (usually inferior first as there is a greater susceptibility to damage here) resulting in an arcuate (usually superior) defect. The arcuate fibres
extend temporally to the fovea to end at the horizontal raphe. This represents the boundary between the superior and inferior nerve tissues from embryological development. Superior and inferior arcuate loss often ends at different positions at this temporal boundary, and the resultant step in the nasal field is significant evidence of arcuate fibre damage (figure 5)

Fig 5.

Nasal step

• Any defect clearly respecting the horizontal midline is likely to be retinal in cause. If sudden onset, this is most likely a vascular incident, as with the altitudinal defect in (figure 6)

Fig 6.

Altitudinal defect
• Any defect respecting the vertical midline is likely to be due to damage within the visual pathway from the chiasma or behind.

• Heteronymous loss is due to chiasmal damage, either due to pressure on the nasal fibres as with the bitemporal loss due to pituitary adenoma (figure 7), or on the temporal fibres, as with the binal loss due to an internal carotid aneurysm.

Fig 7.

Pituitary adenoma

• Damage to the visual pathway posterior to the chiasma results in homonymous loss. This will be more symmetrical (or congruous) the further back in the pathway the lesion is, increasing significantly in congruence posterior to the lateral geniculate nuclei.

• The optic radiations spread through two major lobes of the brain, the parietal and temporal. A common site for damage due to a cerebrovascular accident, damage to the radiations in a patient who survives stroke often leaves a homonymous quadrantanopic defect.

• Damage to the occipital lobe may result in a homonymous hemianopia.

As a significant number of nerve fibres are damaged before detectable field loss results, any repeatable field defect must be treated as important and would usually warrant referral. In the case of a lesion in the visual pathway, this may be an urgent or emergency referral (as with the binal defect mentioned above).

Adapted assessment for early stage glaucoma

Much research has suggested that there is selective nerve fibre damage in glaucoma, with the magnocellular pathway being affected before the parvocellular pathway. Attempts have been made to use stimuli to which the receptors attached to magnocellular ganglion cell fibres are particularly receptive, in an attempt to detect field loss in glaucoma at an earlier stage. Short wave perimetry (or SWAP) is one such attempt (available as an extra on the Humphrey VFA or the Octopus) which uses short wavelength stimuli thought to be magnocellular responsive. Whilst effective, this technique can be difficult for the patient to perform and is more susceptible to extraneous factors such as media opacities.

Another method employs the presentation to various parts of the field a sine wave grating that alternates repeatedly such that the spatial frequency is seen to double. The ability to detect this so-called frequency doubling is again thought to reduce in early glaucoma and so the Zeiss Humphrey FDT may be used in specific glaucoma screening programmes. Some excitement exists currently at machines sensitive enough to detect minute relative afferent pupil defects indicative of ganglion cell loss.

Useful reading

Useful References

Practical Viewing of the Optic Disc Butterworth Heinemann 2003, by Kathleen Digre & James Corbett

Eye Essentials: Assessment & Investigative Techniques Butterworth Heinemann, 2005, by Sandip Doshi, William Harvey

Eye Essentials, Investigative Techniques and Ocular Examination Butterworth Heinemann, 2003, by Sandip Doshi & Bill Harvey

College of Optometrists, Guidance on the Re-Use of Contact Lenses and Ophthalmic Devices


DOCET Clinical Skills DVD, August 2006


Angle Closure Glaucoma Virtual Lecture 2008, Nick Rumney

Interpreting Visual Fields Virtual Lecture 2007, Peter Charlesworth

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Knowledge and best practice in this field are constantly changing. Best practice procedures may change as new research and experience broaden our knowledge. Readers are advised to check the most current advice from the professional bodies and manufacturers of the equipment used. It is the practitioner’s responsibility to make diagnoses, and determine treatment for each individual patient and to ensure appropriate safety precautions are adhered to.

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